

Experimental Studies Related to the use of High Temperature Elastomers as External Damper for Rotating Systems

Soumendu Jana*, V. Arun Kumar
Scientist, Propulsion Division,
National Aerospace Laboratories
Bangalore – 560 017, P.B. No. 1779.
*sjana@prop.cmmacs.ernet.in

ABSTRACT

The widespread application of elastomers in vibration control and isolation may be attributed to the simplicity in design, manufacture and maintenance of such dampers. The stiffness and damping properties of elastomers are dependent on various factors such as strain, frequency of loading, temperature, preloading and geometry of the damper elements. This work is an attempt to evaluate the performance of elastomer dampers using certain high temperature (up to 250 °C) elastomers commercially available, such as, Silicone, Fluorosilicone and Tercite for specific application with emphasis on rotating systems. In the present work Elastomer button cartridges are used in the rotor-bearing rig designed and fabricated for the purpose to evaluate the performance of the damper. Detailed experimentation conducted in the dynamic rig indicates that damping to a reasonable extent could be provided by the elastomers. In order to study the effect of temperature on vibration attenuation in dynamic condition, experiments were conducted by varying the temperature. It is observed that the effect of the temperature on the vibration reduction was only marginal. Further studies might be required to explore the possibilities of enhancing the damping potential. The effort in general has indicated that fluorosilicone might probably be the potential candidate for such applications.

INTRODUCTION

External damping is often introduced to control the vibrations in rotating machinery, thereby achieving safety in operation and reduced maintenance. External damping may be provided in several ways. The most common sources of external damping are bearings and structures. The fluid-film bearings often provide substantial damping to the rotor

system. However, prediction and control of the level of damping is difficult. On the other hand, rolling element bearings provide very little external damping. Rolling element bearings are mounted in series with some kind of mechanical dampers wherever substantial damping is required. In case of mechanical dampers, level of damping is relatively controllable and predictable depending on the type of dampers used. The most common types of mechanical dampers in use are squeeze film and elastomer dampers. In elastomer dampers visco-elastic elements form the interface between the rolling element bearings and the supporting structure. The elastomer elements may be in the form of buttons, O-rings etc.

Several researchers have investigated the application of elastomer dampers for rotating systems. A brief summary of the previously carried out investigations is presented below. Henderson [1] has conducted dynamic tests on a polyurethane foam tape with temperature varying from 79 °F to 94 °F at different frequencies. F. S. Owens [2] describes an experimental work demonstrating a technique for extending the temperature range over which the viscoelastic materials have useful damping. The dynamic response of blends of polyvinyl acetate and polystyrene with a styrene-butadiene and nitrile-butadiene rubber has been investigated over all the glass transition temperatures of the polymers used in the blends. The loss factor and the modulus for the blends were obtained at 200 °F.

Tecza et al. [3] studied the design of an elastomer bearing support for a rotor built to simulate a power turbine of a gas turbine engine crossing two bending critical speeds. Two materials namely viton and polybutadiene have been used for the tests. The valuable information and related methodology for the design of elastomer dampers for rotating systems have been presented comprehensively in [4]. Application of some high temperatures elastomers also have been discussed in this handbook. An attempt has been made [5] using elastomer mount at the rolling element support of a simple modified Jeffcott rotor and its damping characteristics have been studied. A rigorous study [6] on the experimental evaluation of static stiffness of four different types of commercially available elastomer dampers namely silicone, fluoro silicone, viton, tercite has been made. Experiments have been conducted at room temperature as well as at elevated temperature up to 250 °C. The present work is the continuation of this study on static

stiffness, towards the evaluation of the performance of elastomer dampers in a dynamic situation.

EXPERIMENTATION

In order to obtain the performance characteristics of elastomer button cartridges when used as external source of damping defined in terms of vibration attenuation, experiments were conducted in three separate rigs dynamic in nature built for the purpose. Figure 1 shows the schematic of the rig in which elastomer button cartridges could be assembled for testing and photograph of the rig is shown in figure 2. The rotor consists of a mild steel shaft having three mild steel disks mounted on the shaft. The mid-span disks facilitate the attachment of a known unbalance to the rotor. The rotor is supported on two ball bearings placed at the two ends of the shaft which are in turn supported on the elastomer button cartridges. The elastomer button cartridges are accommodated in a hexagonal mild steel block as shown in the figure. Air turbines are suitably mounted towards the end of the rotor shaft to run the rotor at desired speed.

Suitable arrangements are made in the rig to heat up the elastomer buttons at the desired level of temperature. A temperature controller used for the purpose ensures that the temperature of all the button cartridges are maintained at any desired temperature with a variation of $\pm 10^{\circ}\text{C}$.

In order to study the effect of introduction of elastomer in the bearing plane, it is decided to obtain the basic signature of the rig in the absence of the elastomer as the damping medium necessitating a second dynamic test rig designed and built. The schematic of the rig for this study is shown in figure 3. It consisted of the same rotor-disk-bearing assembly of the first dynamic rig, with the two end bearings being held in one end of the two overhanging hollow cylindrical tubes from both sides. The other end of the hollow tube is fixed in a rigid bracket with a facility to change the length of the overhang. This facilitated the variation in the stiffness in the bearing plane, which could be set at any desired value in a limited range. Thus the support stiffness in this rig could be matched with that provided by the elastomer support.

The dynamic rig is appropriately instrumented to acquire unbalance response, rotor speed and response phase information with respect to unbalance location. Non-

contact type inductive probes are used to measure the unbalance response at three different locations one in each of the bearing plane and one at the disc located centrally on the rotating shaft. A photo diode and a light source are used to obtain the phase information of the unbalance response. Since the measurement is being made on the rotating component the initial run out for the rotating component has been obtained. It has also been ascertained whether the run out measured is due to non-circularity in the disc or due to the shaft bow. Arrangements had been made to store the transducer signal on line through a computer aided data acquisition system.

Tests were conducted to obtain the level of damping for an actual application like in an aero engine casing subjected to a load which is 1x dominant. Figure 4 shows the photograph of a squeeze film damper test rig for aero engine casing in which elastomer dampers were introduced at the bolt joint interface and tested. Two types of elastomers namely fluoro silicone and tercite were used in this investigation.

RESULTS & DISCUSSIONS

The performance of the elastomer dampers are evaluated in the present work by analyzing the unbalance responses obtained from the rotor supported with elastomer damper as well as without the dampers but with static stiffness being the same in both the cases. The overall static stiffness of the rotor support with elastomer damper is evaluated by measuring the static deflection of the rotor for a known weight. In case of elastomer support the typical value of static stiffness obtained per bearing is approximately 1.75 MN/m. On the other hand, in case of rotor supported on mild steel tube the overhang length of the tube is adjusted to achieve the support stiffness close to that obtained for elastomer support.

Dynamic tests are conducted by running the rotor through the first critical speed up to 5000 rpm. A known unbalance is incorporated in the rig to generate unbalance excitation. Resulting unbalance responses in vertical direction are measured at the two bearing locations and at the middle disk. Figure 5 shows the measured unbalance responses in the time domain at the rotor speed of 2500 rpm for the case when the rotor is supported with elastomer dampers. The pulse signal indicating the position of the unbalance excitation is also plotted in the same figure. It can be observed from the figure

that the responses at bearing locations are lagging behind the unbalance excitation implying that damping has been provided by the elastomer elements. The peak to peak value of the steady state unbalance responses measured at bearing locations at different rotor speed for different support cases and plotted in figure 6. Measurements are taken at rotor speed as close as possible to the critical speed since capturing the steady state unbalance response at the critical speed is extremely difficult. In figure 6 the resonance peaks for the cases under investigation are not occurring at the same value of rotor speed. This is due to the small variation in the support stiffness values. It may be observed from figure 6 that fluorosilicone has better damping potential as compared to the other elastomers tested.

The experiments under dynamic conditions were conducted varying the temperature of elastomer buttons (silicone and fluorosilicone) at different levels up to 175 °C to study the effect of temperature on the performance elastomer elements. Figures 7 & 8 show the unbalance responses at different temperature level for the silicone and fluorosilicone support cases respectively. It may be concluded from the figures that increase in temperature has marginal effect on the performance of the elastomer dampers. Above the first critical speed the unbalance response is little higher when the elastomers are subjected to higher temperature.

Two types of elastomers namely fluoro silicone and tercite were used in the test rig for testing actual aero engine casing. The measured unbalance responses in vertical direction on the casing are plotted in figure 9. It may be seen from the figure that higher vibration attenuation has been realized when fluoro silicone was used as an external damper. It may be recalled that earlier studies had also supported fluoro silicone as a potential candidate.

CONCLUSIONS

An attempt has been made in this investigative study to explore the possibility of elastomers as external dampers to rotating systems. Three types of locally available elastomers (silicone, fluorosilicone, tercite), which can withstand up to a temperature of 250 °C has been performance tested in three different test rigs. Detailed experimentation

conducted using different rigs indicate that damping to a reasonable extent could be provided by the elastomers. In particular, fluorosilicone has better damping potential as compared to the other elastomers tested. It may also be concluded from this study that increase in temperature has marginal effect on the performance of the elastomer dampers. Further studies might be required to explore the possibilities of enhancing the damping potential.

ACKNOWLEDGEMENT

The author would like to express their thanks to the sponsor (AR&DB, New Delhi, Project No. 1073) of the project for the financial help. The authors would like to thank Mr. U. P. Sankunni, Mr. M. Ananda, Mr. V. Munirathnam, Mr. Mahesh L. Mesta, Mr. R. Rajesh and Mr. P. Babu for their kind cooperation and help during the experimentation.

REFERENCES

1. J. P. Henderson, "Energy dissipation in a vibration damper utilizing a viscoelastic suspension", Shock & Vibration Bulletin, No. 35, Part 7, pp 213-227, April 1966.
2. F. S. Owens, "Elastomers for damping over wide temperature ranges", Shock & Vibration Bulletin, No. 36, Part 4, pp 25-35, 1967.
3. J. A. Tecza, A. J. Smalley, M. S. Darlow, R. E. Cunningham, S. W. Jones, "Elastomer mounted rotors – an alternative for smoother running turbomachinery", ASME Paper 79-GT-149.
4. M. S. Darlow, E. Zorzi, "Mechanical Design Handbook for Elastomers", NASA Contractor Report 3423, June 1981.
5. V. Arun Kumar, M. Jayaraman, G. Giridhara, G. R. Srinivasa, "Unbalance response of a modified Jeffcott rotor with external elastomer dampers", NCABE, 1994.
6. V Arun Kumar, S Jana, L Srikanth, "Parametric Studies Related to Static Stiffness of Elastomers to be used as Dampers for Rotating Systems", Proceedings 3rd International Conference on Industrial Tribology, Tata Steel, Jamshedpur, India, 8-11th April. 2002, pp. 9.46-9.56.

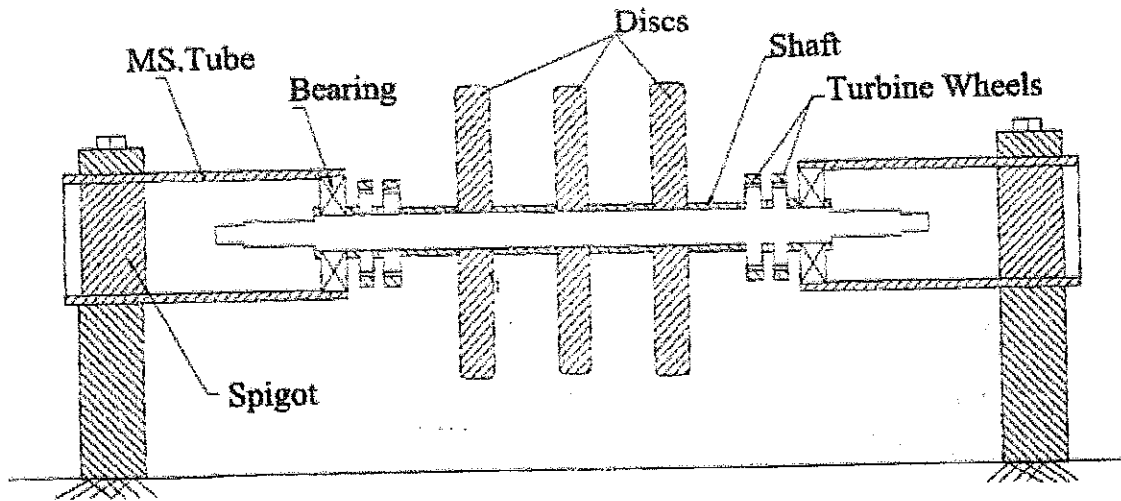


Fig. 3 Schematic Diagram of the Dynamic Test Rig without Damper

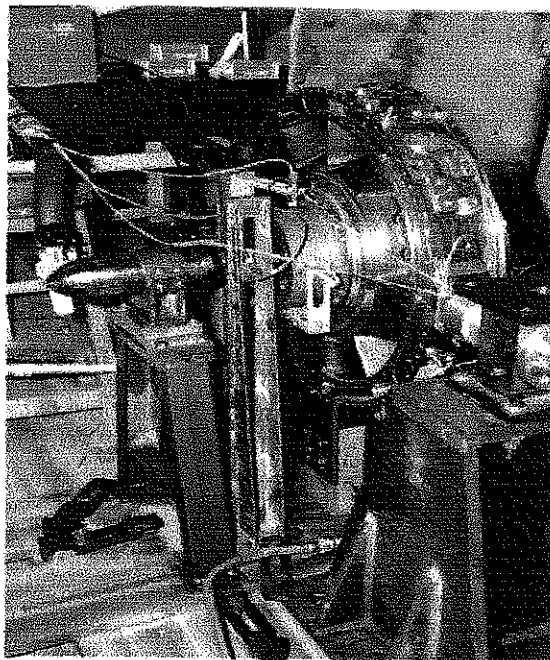


Fig. 4 Photograph of the Test Rig for SFD Damper in Aero Engine Casing

Fig. 5 Response Signal along with Excitation Pulse (2500 RPM, Elastomer Support)

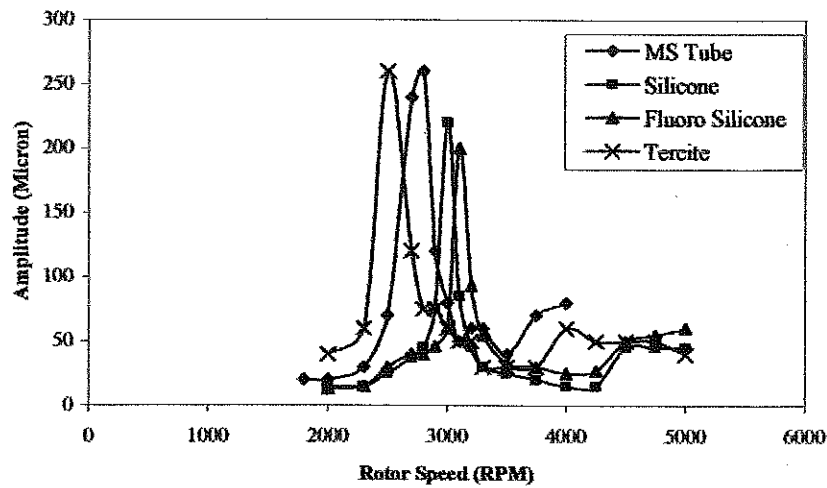


Fig. 6 Comparison of Unbalance Response Measured at Bearing (Rotor Supported on MS Tube and Elastomer Dampers)

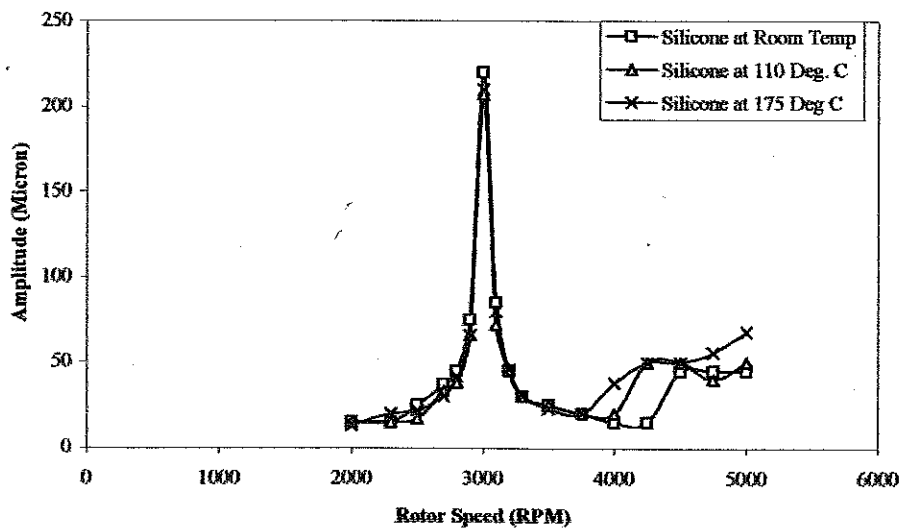


Fig. 7 Unbalance Response at Bearing for Rotor Supported on Silicone Damper

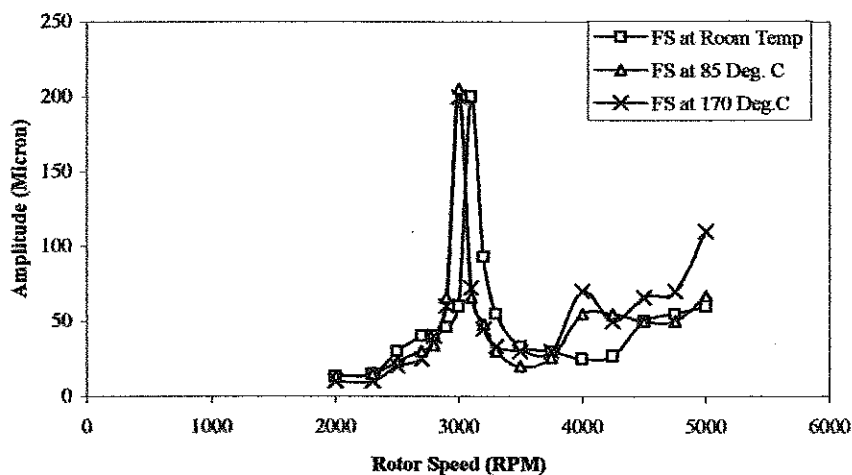


Fig. 8 Unbalance Response at Bearing for Rotor Supported on Fluorosilicone Damper

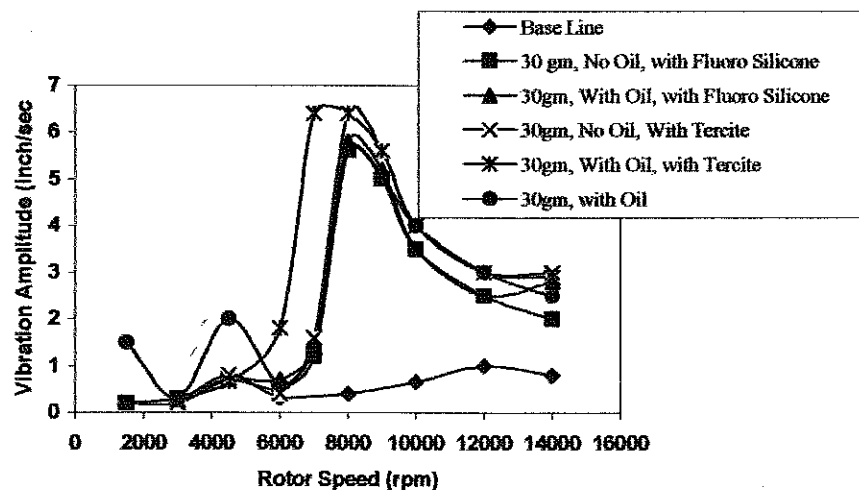


Fig. 9 Vibration amplitude measured at casing (Titanium)